

FORM PTO-1390
(REV 12-29-99)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

8733.20070

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/529948 ✓

INTERNATIONAL APPLICATION NO.

PCT/BY98/00008

INTERNATIONAL FILING DATE

25 September 1998

PRIORITY DATE CLAIMED

6 August 1998

TITLE OF INVENTION

LIQUID-CRYSTAL DISPLAY (VARIANTS) AND THE METHOD OF ITS FABRICATION

APPLICANT(S) FOR DO/EO/US Victor A. KONOVALOV; Anatoly A. MURAVSKY; Sergey
E. YAKOVENKO and Sergey N. TIMOFEEV

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:

White Advance Serial Number Postcard
Various PCT Documents

17. ☐ The following fees are submitted:**BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :**

Neither international preliminary examination fee (37 CFR 1.482)
nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO
and International Search Report not prepared by the EPO or JPO \$970.00

International preliminary examination fee (37 CFR 1.482) not paid to
USPTO but International Search Report prepared by the EPO or JPO \$840.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but
international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$670.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)
and all claims satisfied provisions of PCT Article 33(1)-(4) \$96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =**CALCULATIONS** PTO USE ONLY

\$ 840.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30
months from the earliest claimed priority date (37 CFR 1.492(e)).

\$

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	35 - 20 =	15	X \$18.00
Independent claims	3 - 3 =		X \$78.00

\$ 270.00

\$

MULTIPLE DEPENDENT CLAIM(S) (if applicable)

+ \$260.00

\$ 260.00

TOTAL OF ABOVE CALCULATIONS =

\$ 1,370.00

Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement
must also be filed (Note 37 CFR 1.9, 1.27, 1.28).

\$

SUBTOTAL =

\$ 1,370.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30
months from the earliest claimed priority date (37 CFR 1.492(f)).

\$

+

TOTAL NATIONAL FEE =

\$ 1,370.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

+

\$ 40.00

TOTAL FEES ENCLOSED =

\$ 1,410.00

Amount to be
refunded:

\$

charged:

\$

a. ☒ A check in the amount of \$ 1,410.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees.
A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any
overpayment to Deposit Account No. 50-0911. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Song K. Jung
LONG ALDRIDGE & NORMAN LLP
Suite 601
701 Pennsylvania Avenue, N.W.
Washington, D.C. 20004
Phone: (202) 624-1200

SIGNATURE:

Song K. Jung

NAME

35,210

REGISTRATION NUMBER

09/529948

LIQUID-CRISTAL DISPLAY AND THE METHOD OF ITS FABRICATION

5

Field of the Invention

Invention is related to the field of electronics and can be used for making information displays, in particular, liquid crystal (LC) indicators, screens, panels etc.

10

Prior Art

The drawback of the majority of liquid crystal displays is a strong dependence of their transmission on the angle of light incidence [S.T.Wu, C.S.Wu, SID Digest 27, 763 (1996)-1] and, as a result, decrease of contrast and even inversion of transmission levels at some observation angles. For improving these characteristics of displays in many cases a set of retardation plates is used [N.Yamagishi, H.Watanabe, K.Yokoyama, 'Japan Display 89', 316 (1989)-2], which increases the cost of the device and does not resolve the problem of color inversion.

20

The most promising from this point of view are multi-domain LC displays, in which a single pixel contains areas with various orientations of the liquid crystal in the plane of substrates [M.Schadt, Proc.SID'97, 24.1 (1997)-3].

25 There is an information display [K.-H.Kim, S.-B.Park, J.-U.Shim, J.-H.Souk, J.Chen, SID 98
FEST, 1085 (1998)-4], which consists of two plane and parallel substrates with electrodes
deposited at least on one of them, the said substrates are overlaid with the electrodes facing
each other. The space between the substrates is filled with a homeotropically aligned liquid
crystal mixture possessing positive anisotropy. From the outside the substrates are surrounded
30 by two crossed polaroids. In the off state this display does not transmit the light. After electric
voltage of the opposite polarity is applied to the neighboring electrodes at one of the
substrates, a parabolic electric field is created between the said electrodes, which reorients the
liquid crystal parallel to it. In this way it is possible to orient LC molecules between the

electrodes in two different directions (the so-called two-domain structure) and as the result, the viewing angle of such display is improved considerably. To maximize the brightness polaroids are oriented at 45° to the electrodes. Nevertheless, low brightness is the drawback of this display, as well as of other displays based on director re-switching in the plane of the substrates [M.Ohta et al, Asia Display'95, 707 (1995)-5]. Another drawback is that it is impossible to have more than two domains in a pixel.

There is display [S.-C. A.Lien, R.A.John, Patent USA, US5,309,264-6], [S.-C. A.Lien, R.A.John, et al, SID 98 DIGEST, 1123 (1998)-7], in which two principles are used to have domain structure: fringe field, which arises at the edge of the electrode after applying electric field, and ridge field at the opposite slopes of the protrusions formed lithographically at the opposite substrates with color filters. Protrusions act as elements which incline LC director from the normal to the substrate. The space between the substrates is filled with homeotropically aligned liquid crystal possessing negative dielectric anisotropy. Liquid crystal molecules are aligned perpendicularly to the substrates surface and in the off state this display does not transmit the light (crossed polaroids) and only on the slopes of protrusions the molecules deviate from the normal to the angle which equals the angle between the slope of the protrusion and the substrate. At the slopes the molecules are pre-tilted in different directions, but pre-tilt is not high and therefore it does not perturb optical parameters of display in the off state. Within the pixel protrusions are oriented so that the pre-tilt direction coincides with the direction of the fringe field which arises at the long edge of the pixel (the pixel has elongated rectangular shape). In such display co-action of the fringe electric field and protrusions result in reorienting LC molecules within the pixel in different directions relative to the long axes of the protrusions. The drawback of such device is that although it is possible to have four domains within a pixel (this number of domains is optimal for equalizing optical characteristics in different directions), but in a real display these domains have different area and it is difficult to equalize optical characteristics completely. Besides this, the fringe field which arises around the pixel after applying electric voltage is distorted by connecting buses and this results in non-uniform switching of various domains within a pixel.

The closest to the proposed devices and method is technical reference [A.Takeda et al, SID 98 DIGEST, 1077 (1998)-8]. This display consists of two substrates with the pattern of electrodes

deposited on them, on the said electrodes protrusions are deposited photolithographically with the slopes in different directions. These protrusions like similar elements in [7] tilt the LC director from the normal of the substrate. The space between the substrates is filled with homeotropically aligned liquid crystal possessing negative dielectric anisotropy. In the off state the LC molecules are orthogonal to the substrates except those in the areas where the protrusions are displaced. At the slopes of the protrusions the molecules are pre-tilted to the angle, which equals the angle between the slope and the substrate. This pre-tilt is not high and does not perturb optical characteristics of the display in the off state and in crossed polaroids display does not transmit the light. When the voltage is applied to the electrodes at the opposite substrates this pre-tilt is sufficient to initiate molecular reorientation in different directions within the pixel area. This leads to appearing domains and makes viewing angle more uniform. The drawback of this display is low brightness (30% of conventional single-domain display) because of two factors: protrusions occupy more than 30% of the display area and to realize four domains very specific pattern of the protrusions is required, which leads to additional losses of light. Besides this to make this display two additional photolithographies are required.

Summary of the Invention

Present invention is aimed to make displays with wide viewing angle possessing higher brightness in transmission mode and to develop more simple method for making such displays.

This target is achieved by making in display with multiple pixels deflecting elements of dielectric material and depositing them over the electric conductive coating at least on one of the substrates the space between which is occupied by liquid crystal. Dielectric elements can have profile as from the liquid crystal side, so from the side of the substrate. They can be deposited on both, as well as only on one substrate. Dielectric deflecting elements may be displaced along the perimeter of the pixel as well as across its area. After applying electric voltage to the electrodes at the opposite substrates at the interface LC-dielectric deflecting element distortions of the electric field appear with the component of electric field parallel to the substrates. Direction of this in-plane component is determined by the configuration of the dielectric deflecting elements. The value of this component is sufficient to reorient liquid crystal in different directions and hence to generate different domains within the pixel area and to make optical properties of display independent of the viewing angle. Unlike in the known display [8],

dielectric elements take not more than 5-10% of the pixel area and proposed display has higher brightness. At the same time configuration of the dielectric elements is capable of obtaining two- as well as four domain displays for any real pixel shape.

5 Brief Description of the Drawings

Figs.1-2 show the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method with various displacement of the dielectric deflecting elements.

10

Fig.3 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method, in the said display the dielectric deflecting elements are displaced at the color filters substrate and play the role of the black mask.

15

Fig.4 shows the top view of the displays fabricated according to the proposed method with various displacement of the dielectric deflecting elements.

20

Figs.5-8 show the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method with various displacement of the dielectric deflecting elements in the cases when these elements have profiled thickness at the side of the substrate.

Fig.9 shows the cross-section (a) and the top view (b) of the proposed two-domain display, fabricated according to the proposed method with planar alignment of the liquid crystal.

25 Detailed Description of the Preferable Embodiments

The proposed displays are fabricated as following.

30

On one or both substrates with aligning layer deposited on them dielectric deflecting elements are patterned on the top of the last electric conductive layer. Resistivity of the deflecting elements should not be substantially lower than that of the liquid crystal material, the last is usually higher than 10^8 Ohm/cm.

Deflecting elements are usually formed photolithographically. Most often they have shape of solid or dashed lines with the intervals between the dashes 5-30 μm , the line-width 2-3 μm and larger and the height (or depth) from 0.1 μm up to the LC thickness. The cross section of the deflecting dielectric elements may have the shape of any geometric figure, such as triangle, turned with one side to the substrate, trapezium, rectangle, semicircle e.t.c. Deflecting dielectric elements are patterned to have the form of lines of any type surrounding the pixel. If pixel has elongated shape, it may be subdivided by deflecting elements into squares, or rectangles with the shape close to squares. Deflecting elements may be displaced in the gap between the electrodes and cover part of the electrode with the width comparable to the height of the element in order to avoid the influence of the fringe field on the LC orientation. The area between the deflecting elements may be filled with supplementary coatings (variants with the deflecting dielectric elements profiled from the side of the substrate). Supplementary coatings may play the role of planarizing film, or color filters matrix, or various conductive layers. This may be the areas of the substrate, between which the wells are made, which are filled with the deflecting dielectric elements.

At the second substrate deflecting elements are also deposited to have a shape of squares, or rectangles with the shape close to squares with the same dimensions as on the first substrate, or with different dimensions, or having shape of solid, or dashed lines of various form.

In the case when matrix of color filters is formed at the second substrate, deflecting dielectric elements usually align with the black matrix, or replace them by dielectric black matrix. In the latter case one technological operation is reduced.

Deflecting dielectric elements on different substrates can be made of different materials. For example, when on the color filter substrate deflecting dielectric elements are replaced by the black matrix, on the second substrate they are made from as transparent material as possible to reduce the losses of light. The height of the deflecting dielectric elements may vary across the substrate and may be different on different substrates. The first case can be useful to make displays with variable viewing angle across the display area.

At the next stage aligning layer for homeotropic or planar alignment is deposited at the substrates.

To control the gap between the substrates in the case when deflecting elements are deposited only on one substrate conventional spacers, such as spheres, or fibers, or particles of definite dimensions made of inorganic as well as organic materials are used. In the case when deflecting elements are deposited on the electrodes on both substrates and have profile from the side turned to the liquid crystal, additional spacers are not necessary because deflecting dielectric elements play the role of spacers. Simultaneously, the display becomes more rugged and the LC layer thickness can be easily varied during fabrication process.

At the next stage of fabricating display with deflecting dielectric elements deposited on one substrate this substrate is overlaid with another one, containing pattern of electrodes, aligning layer and conventional spacers with the said electrodes faced to each other on both substrates and is sealed along the perimeter.

In the case the display has deflecting dielectric elements on both substrates with the profile from the liquid crystal side to obtain equally good viewing characteristics for all observation angles these deflecting elements are aligned so that the crossings of the lines on one substrate be as close as possible to the centers of the squares formed by deflecting dielectric elements on the second substrate. After this display is sealed.

If at least on one of the substrates deflecting dielectric elements are profiles from the side of the substrate, then the substrates are aligned similarly to the previous case, but conventional spacers are used to control the gap between the substrates.

As a rule, liquid crystal domains are formed of equal size to make viewing characteristics independent of angle. Nevertheless, they can have different size if display should have specific viewing characteristics.

The space between the substrates is filled with liquid crystal.

This liquid crystal can possess either positive or negative dielectric anisotropy. Consequently, the said liquid crystal may have either planar or homeotropic alignment. Planar aligning material is rubbed. The angle between the rubbing direction and the deflecting dielectric elements may

be taken in the range $0^\circ - 180^\circ$. Both non-chiral and chiral liquid crystal materials are appropriate. In the case it is chiral and has planar alignment it may be twisted to the angle from 0° to 360° . If it has homeotropic alignment, its twist angle should be chosen so that $d/p < 0.5$ (here d - LC layer thickness, p - its spontaneous helix pitch).

5

In the proposed displays liquid crystal doped with a dichroic dye can be used and then such display may operate without polaroids and information is displayed due to light absorption by the dye molecules. The dichroic ratio of the dye can be larger or smaller than 1 and liquid crystal may be chiral or non-chiral.

10

Proposed displays can operate in reflective mode. In such a case one of the substrates and the electrode deposited on it are made non-transparent (reflective). The image is obtained with one polaroid.

15

Fig.1 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On two plane glass substrates 1 and 2 0.5-2 mm thick and with linear dimensions on the range of 1 cm to several decimeters transparent electrodes from conductive coating 3 having thickness 70-150 nm and surface resistivity 10-2000 Ohm/ \square are deposited in vacuum from the oxide of the indium-tin alloy. The desirable electrode pattern is made photolithographically. On one substrate deflecting dielectric elements 5 are formed from photoresistive dielectric material, for example AR P-310, which have the shape of crossing lines with the pitch 100 μm , width 5-7 μm and height 2.5-3 μm . Both substrates 1, 2 are covered with homeotropic aligning layer 4, for example AL-655 (JSR), 20-100 nm thick. Conventional spacers, like plastic spheres 3-6 μm in diameter, are deposited on one of the substrates 1, 2.

20

25

The substrates 1, 2 are overlaid with the aligning layers 4 faced to each other and fixed together with the sealing material having epoxy base, for example UHU plus endfest 300. The space between the substrates 1, 2 is filled with liquid crystal possessing negative dielectric anisotropy, such as MLC-6608. So made display transmits 45-50% of light in the on state in crossed polaroids (for 100% we take the light transmitted by display in the off state between the parallel polaroids).

30

Fig.2 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On two plane glass substrates 1 and 2 on the top of the conductive layer 3 deflecting dielectric elements (5), (6) are deposited in the form of crossing lines with the width 5-6 μm , their height is 2.0-2.5 μm and the pitch - 100 μm . The substrates 1, 2 are aligned so, that line crossings on one substrate are close to the centers of the squares formed by the lines on the second substrate. The crossings of the lines on different substrates are used as spacers. Single pixel abcd is surrounded by thicker vertical lines and two horizontal lines placed at the bottom substrate 1. So made display transmits 75-80% of light in the on state in crossed polaroids.

Fig.3 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method, in which deflecting elements 5 at the color filters substrate are made of non-transparent dielectric material and have the form of lines 5-15 μm thick with the height 2-2.5 μm above the color filters surface. Simultaneously these deflecting elements play the role of the black matrix. Pixel abcd is surrounded by peripheral vertical lines and two horizontal lines placed at the bottom substrate 1. In other aspects the display is made similarly to that one described in fig.2. This display has brightness 60-80% in the on state.

Fig.4 shows the top view of the proposed displays fabricated according to the proposed method with various displacements of the deflecting dielectric elements 1 and 2 on the bottom and the top substrates respectively. Single pixel is displayed. In other aspects the display is made similarly to that one described in fig.2. This display has brightness 75-80% in the on state.

Fig.5 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On the bottom 1 and top 2 substrates containing the electrodes pattern 3 deflecting dielectric elements 5 and 6 are deposited. On the bottom substrate 1 the area between the dielectric deflecting elements is filled with a supplementary layer 7 possessing dielectric constant different from that of the deflecting elements (dielectric deflecting elements are profiled from the side of the substrate). On the top of all patterns on both substrates 1, 2 homeotropically aligning layer 4 is deposited. Conventional spacers, like plastic spheres 3-6 μm in diameter, are used. Pixel abcd is surrounded by thicker vertical lines

and two horizontal lines placed at the bottom substrate 1. In other aspects the display is made similarly to that one described in fig.1. This display has brightness 75-80% in the on state.

Fig.6 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On the bottom 1 and top 2 substrates containing the electrodes pattern 3 deflecting dielectric elements 5 and 6 are deposited. On the bottom substrate 1 the area between the dielectric deflecting elements is filled with a supplementary layer 7 possessing dielectric constant different from that of the deflecting elements (dielectric deflecting elements are profiled from the side of the substrate). On the top of the supplementary layer 7 conductive coating 3 is deposited. On the top of all patterns on both substrates 1, 2 homeotropically aligning layer 4 is deposited. Conventional spacers are used. Pixel abcd is surrounded by thicker vertical lines and two horizontal lines placed at the bottom substrate 1. In other aspects the display is made similarly to that one described in fig.1. This display has brightness 75-80% in the on state.

Fig.7 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On the bottom 1 and top 2 substrates containing the electrodes pattern deflecting dielectric elements 5 and 6 are deposited. On the bottom substrate 1 the area between the dielectric deflecting elements 5 is filled with a supplementary layer 7 possessing dielectric constant different from that of the deflecting elements (dielectric deflecting elements are profiled from the side of the substrate). On the top of the supplementary layer 7 conductive coating 3 is deposited. On the top of conductive coating 3 the film made of material of the deflecting dielectric element is displaced and covered with the aligning film 4. Conventional spacers are used. Pixel abcd is surrounded by thicker vertical lines and two horizontal lines placed at the bottom substrate 1. In other aspects the display is made similarly to that one described in fig.1. This display has brightness 75-80% in the on state.

Fig.8 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On the bottom 1 and top 2 substrates containing the electrodes pattern deflecting dielectric elements 5 and 6 are deposited. On the bottom substrate 1 the area between the dielectric deflecting elements 5 is filled with a supplementary layer 7 which is made of the same material as the substrate (in a real process the grooves are made in the substrate in advance and after depositing electric conductive coating the grooves are filled

with the dielectric deflecting elements 5). On the top of the supplementary layer 7 conductive coating 3 is deposited. On the top of conductive coating 3 the aligning film 4 is displaced. Conventional spacers are used. Pixel abcd is surrounded by peripheral vertical lines and two horizontal lines placed at the bottom substrate 1. In other aspects the display is made similarly to that one described in fig.1. This display has brightness 75-80% in the on state.

Fig.9 shows the cross-section (a) and the top view (b) of the proposed display, fabricated according to the proposed method. On two plane glass substrates 1, 2 on the top of the conductive layer 3 deflecting dielectric elements 5, 6 are deposited. On one substrate, let us tell substrate 1, deflecting elements 5 have the form of crossing dielectric lines and on another substrate, for example 2, they look like dielectric lines. Lines on the both substrates 1, 2 have the width 5-6 μm , their height is 2.0-2.5 μm and the pitch - 100 μm . The substrates 1, 2 are aligned so, that the lines on substrate 2 cross the sides of the rectangles formed by the lines on the substrate 1 close to their centers. The crossings of the lines on substrate 1 with the lines on the substrate 2 are used as spacers. Planar aligning layer 4, for example AL-3046 (JSR), is deposited on both substrates 1, 2. The substrates 1, 2 are rubbed parallel to each other and perpendicular to the lines on the substrate 2. The space between the substrates 1, 2 is filled with a nematic liquid crystal ZLI-3497-000 possessing positive dielectric anisotropy. Single pixel abcd is surrounded by thicker vertical lines and two horizontal lines placed at the bottom substrate 1. So made display transmits 85-90% of light in the off state in crossed polaroids.

The proposed display with homeotropic alignment of the liquid crystal possessing negative dielectric anisotropy operates as following.

In the state without electric field LC molecules are aligned orthogonal to the substrates 1, 2 in the whole area except the slopes of the deflecting dielectric elements 5, 6, in the case their profile is from the liquid crystal side. In difference to [7,8], in the proposed display the slopes of the deflecting elements are either very steep (the angle with the substrate normally is bigger than 30-40°), or they are absent at all, in the case they are profiled from the substrate side. So distortions of the liquid crystal alignment either have limited size, or absent at all and do not perturb optical parameters of the display. Therefore in the off state this display does not transmit light in the crossed polaroids.

After applying electric field liquid crystal reorients not uniformly across the pixel area, but according to the direction of the parallel to the substrates component of the electric field which appears at the LC - dielectric interface. This way domains with different (including opposite) orientation of the liquid crystal appear within the pixel area. Under various observation angles different domains have different transmittance and transmittance of the pixel as a whole equals some averaged value. Due to this, inversion of the transmission levels of LC display under various observation angles is suppressed, similarly to the effect observed in [7,8]. To increase the viewing angle (to increase the contrast under oblique observation angles) phase retarders [2] may be used in the proposed display.

Display with LC possessing positive dielectric anisotropy and aligned parallel to the substrates operates in a similar way. The difference is that in the off state this display transmits light in crossed polaroids. After applying electric field LC reorients in different directions depending on the direction of the in-plane with the substrates component of the distorted electric field, which is created at the LC-dielectric interface. As the result, viewing characteristics become similar for different observation angles. In the on state display becomes non-transparent.

Summarizing the analysis of the proposed display and the method for its fabrication one can tell, that using conventional technology for making LC displays, in which only one technological photolithographic stage is added for making deflecting dielectric elements, it is easy to obtain display with wide viewing angle. The number of domains, their displacements, as well as proportion of their areas can be easily varied by varying photolithographically made pattern. Besides this, in transmission mode the losses of light are in the range of 10-20% in comparison with conventional single-domain displays, which are not essential for the desk-top displays.

CLAIMS

1. Liquid crystal display with plurality of pixels comprised of two plane substrates (1),
5 (2) with electric conductive layers deposited on the faced to each other sides of the substrates
(1), (2), covered with aligning layers (4) and with liquid crystal filling the space between the
substrates (1), (2), having deflecting elements (5), (6) and, if required, black matrix,
characterized in that

at least on one substrate deflecting elements (5), (6) are dielectric and are displaced over
10 electric conductive layers along the perimeter of each pixel.

2. Display according to claim 1, characterized in that, deflecting dielectric elements
(5), (6) are made of material with the resistivity equal, or exceeding the resistivity of the liquid
crystal.

3. Display according to claims 1-2, characterized in that, deflecting dielectric elements
15 (5), (6) are additionally displaced within the area of each pixel.

4. Display according to claims 1 or 2, characterized in that, the said black matrix is
made of deflecting dielectric elements (5), (6).

5. Display according to claims 1-4, characterized in that, deflecting dielectric elements
(5), (6) have the height in the interval 0.1-1 value of the liquid crystal thickness.

6. Display according to claim 1, characterized in that, deflecting dielectric elements
20 (5), (6) are displaced on both substrates (1), (2) over the electric conductive layers.

7. Display according to claim 6, characterized in that, deflecting dielectric elements
(5), (6) which are displaced over the electric conductive layers are made of different materials.

8. Display according to claims 1-7, characterized in that, deflecting dielectric elements
25 (5),(6) have varying height.

9. Liquid crystal display with plurality of pixels comprised of two plane substrates (1),
(2) with electric conductive layers deposited on the faced to each other sides of the substrates
(1), (2), covered with aligning layers (4) and with liquid crystal filling the space between the
substrates (1), (2), having deflecting elements (5), (6) and, if required, black matrix,
30 characterized in that

at least on one substrate deflecting elements are dielectric and placed over the electric
conductive layer and the area between them is filled with a supplementary coating (7).

10. Display according to claim 9, characterized in that, on the top of the supplementary coating (7) additional conductive layer is deposited.

11. Display according to claims 9 or 10, characterized in that, over the said dielectric deflecting elements (5), (6) and supplementary coating (7) additional layer is formed made of the material of the said deflecting dielectric elements (5), (6).

12. Display according to claim 9, characterized in that, the said dielectric deflecting elements (5), (6) are made of material with the resistivity equal or exceeding that of the said liquid crystal.

13. Display according to claims 9-12, characterized in that, deflecting dielectric elements (5), (6) are additionally displaced within the area of each pixel.

14. Display according to claims 9 or 13, characterized in that, the said black matrix is made of deflecting dielectric elements (5), (6).

15. Display according to claims 9-14, characterized in that, deflecting dielectric elements (5), (6) have the height exceeding 0.1 of the liquid crystal thickness.

16. Display according to claim 9, characterized in that, deflecting dielectric elements (5), (6) are displaced on both substrates (1), (2) over the electric conductive layers.

17. Display according to claim 16, characterized in that, deflecting dielectric elements (5), (6) which are displaced over the electric conductive layers are made of different materials.

18. Display according to claims 9-16, characterized in that, deflecting dielectric elements (5), (6) have varying height.

19. Display according to claim 9, characterized in that, the supplementary coating (7) is made of the same material as the substrate.

20. Display according to claim 19, characterized in that, on the top of the supplementary coating (7), which is made of the same material as the substrate, electric conductive layer is deposited.

21. The method for making liquid crystal display with plurality of pixels comprised of depositing electric conductive and aligning layers on the faced to each other sides of two plane substrates, of subsequent filling liquid crystal in the space between the substrates, of forming deflecting elements and, if required, color filters and black matrix, characterized in that at least on one substrate deflecting elements are made dielectric and are displaced over the electric conductive layer.

22. The method according to claim 21, characterized in that, deflecting dielectric elements are made of material with the resistivity equal to or exceeding that of the liquid crystal.

23. The method according to claims 21 or 22, characterized in that, deflecting
5 dielectric elements are formed on both substrates.

24. The method according to claim 23, characterized in that, deflecting dielectric elements are formed of different materials

25. The method according to claims 21-24, characterized in that, the area between the deflecting dielectric elements is filled with supplementary coating.

10 26. The method according to claim 25, characterized in that, on the top of the supplementary coating additional electric conductive layer is deposited.

27. The method according to claims 24 or 25, characterized in that, on the top of the supplementary coating additional layer made of the material of the deflecting dielectric elements is deposited.

15 28. The method according to claim 21, characterized in that, the supplementary coating is made of the same material as the substrate.

29. The method according to claim 25, characterized in that, on the top of the supplementary coating electric conductive layer is deposited.

20 30. The method according to claims 21-23, characterized in that, the black matrix is made of the material of the deflecting dielectric elements.

31. The method according to claim 21, characterized in that, deflecting dielectric elements are formed with the height exceeding 0.1 of the liquid crystal thickness.

25

30

09/529948

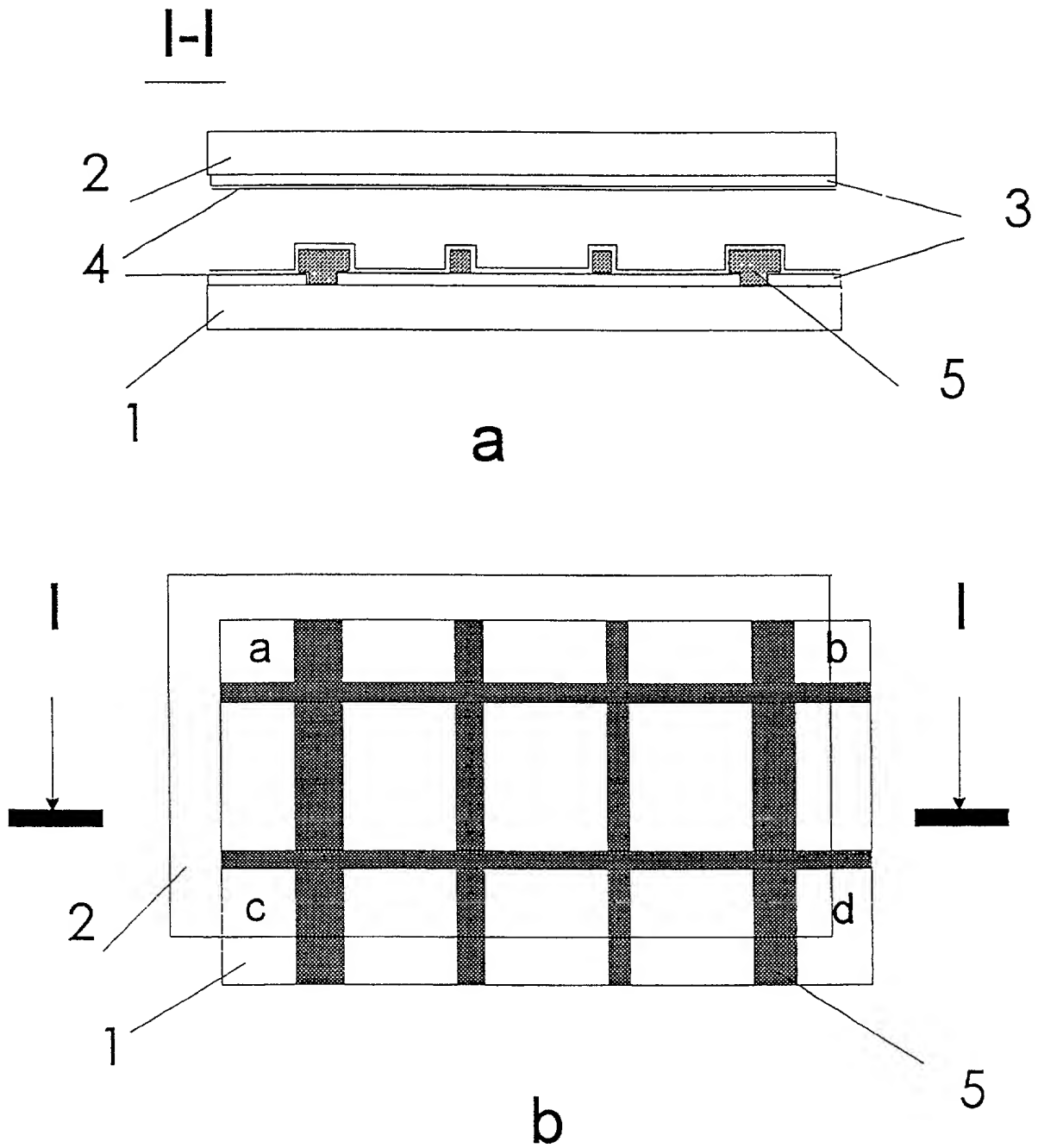


Fig. 1

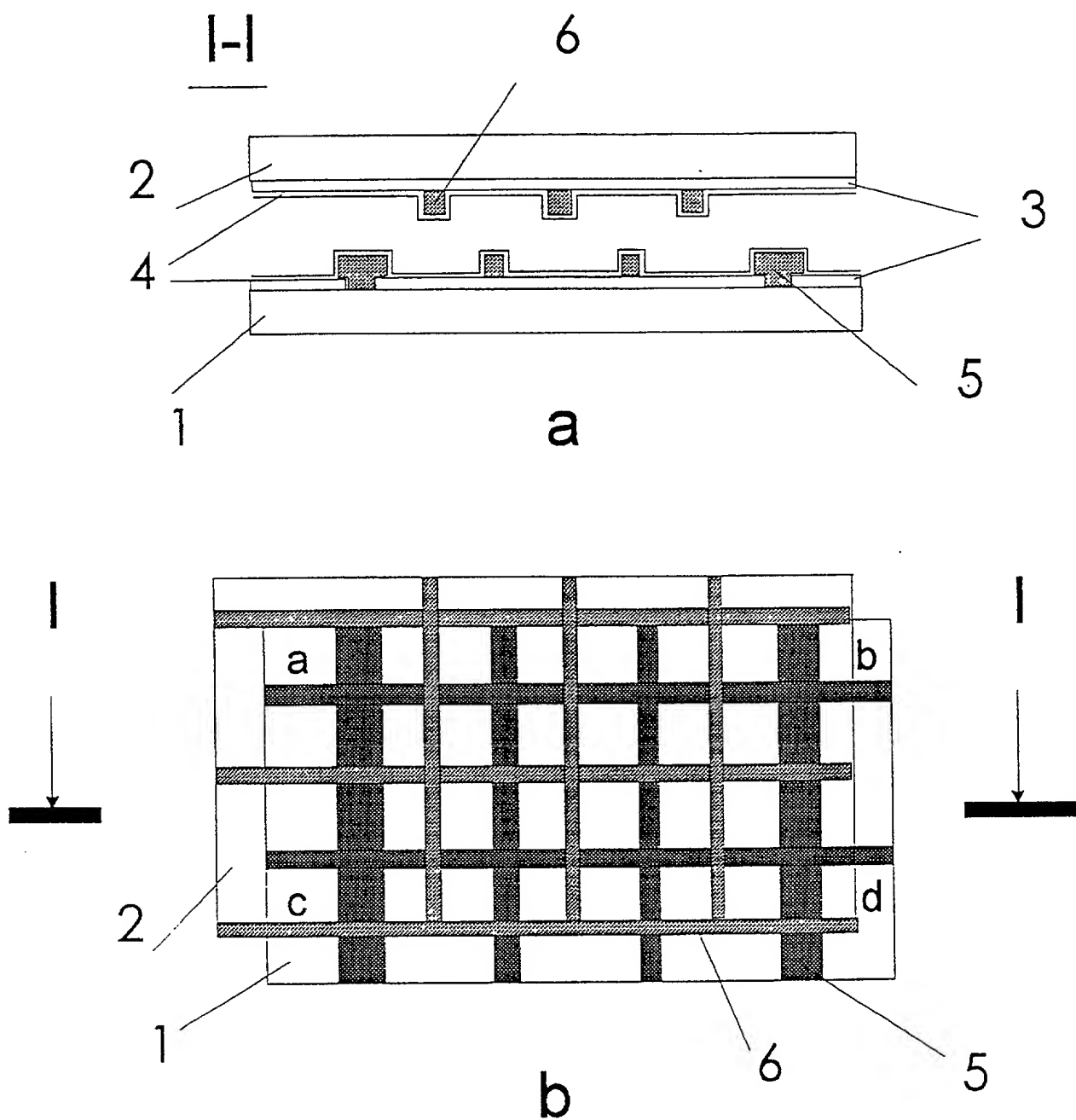


Fig.2

09/529948

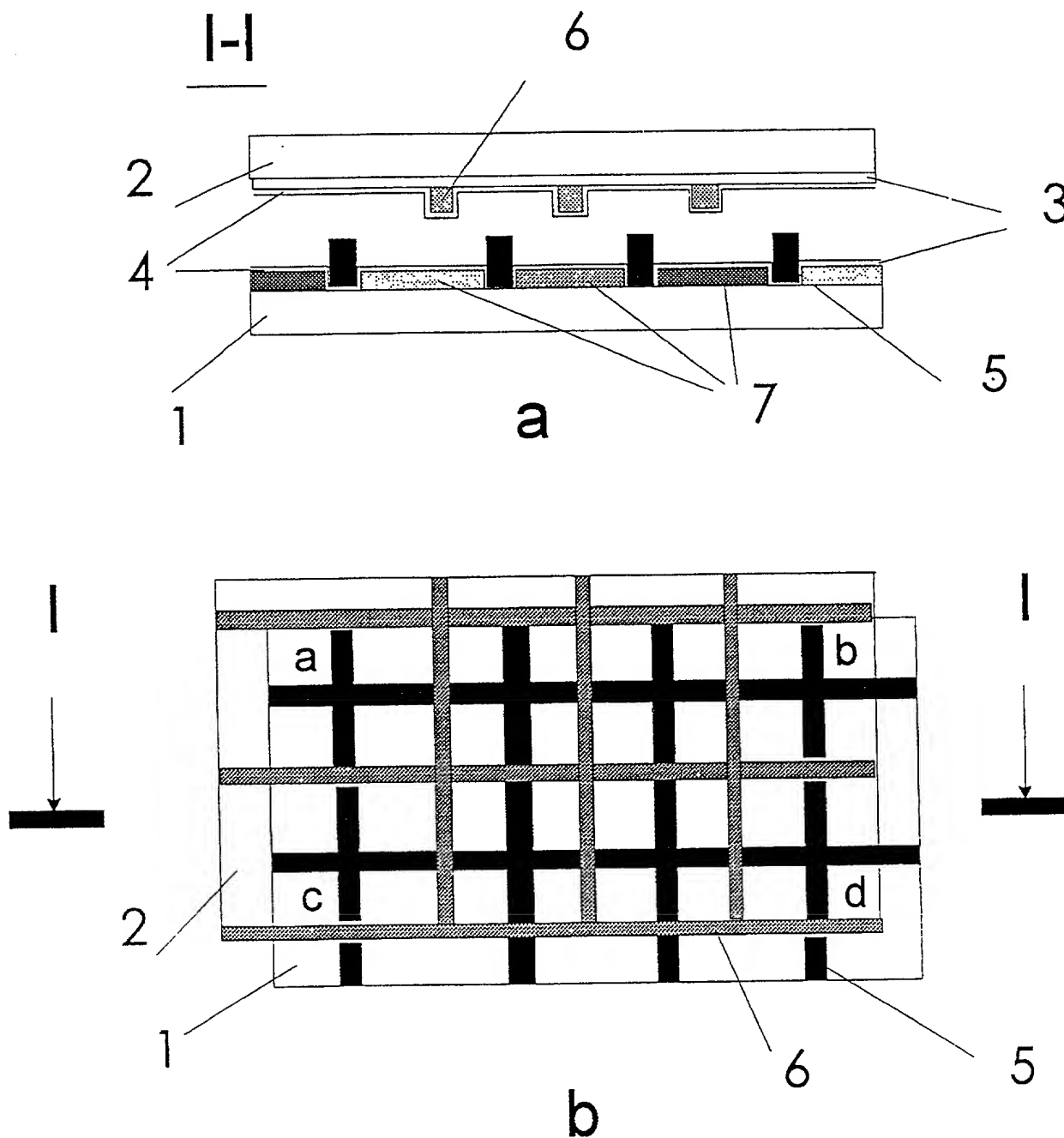
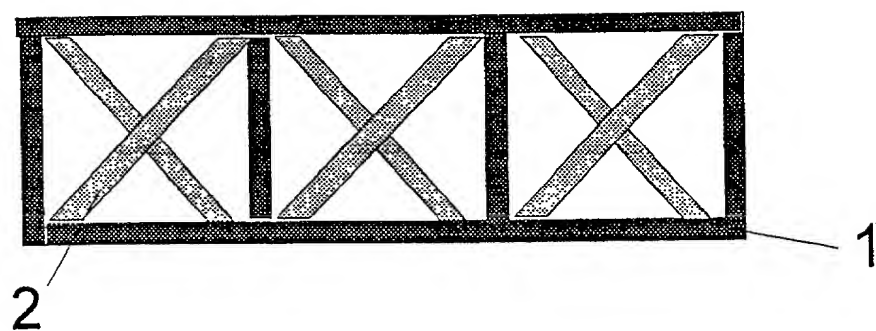
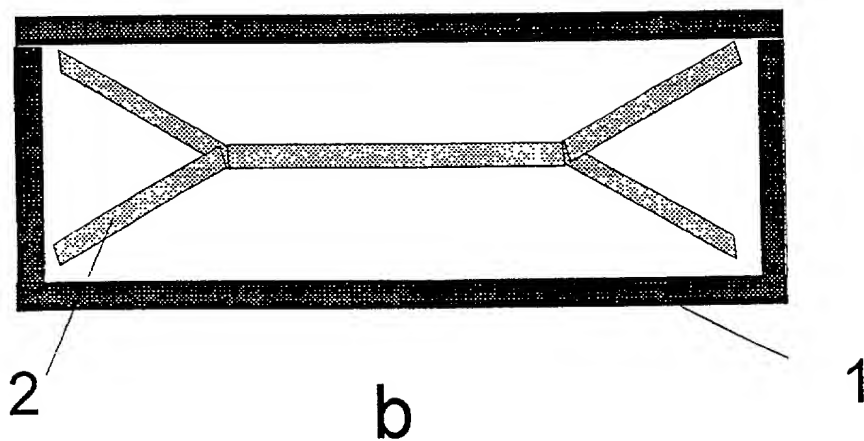


Fig. 3

09/529948



a



b

Fig. 4

09/529948

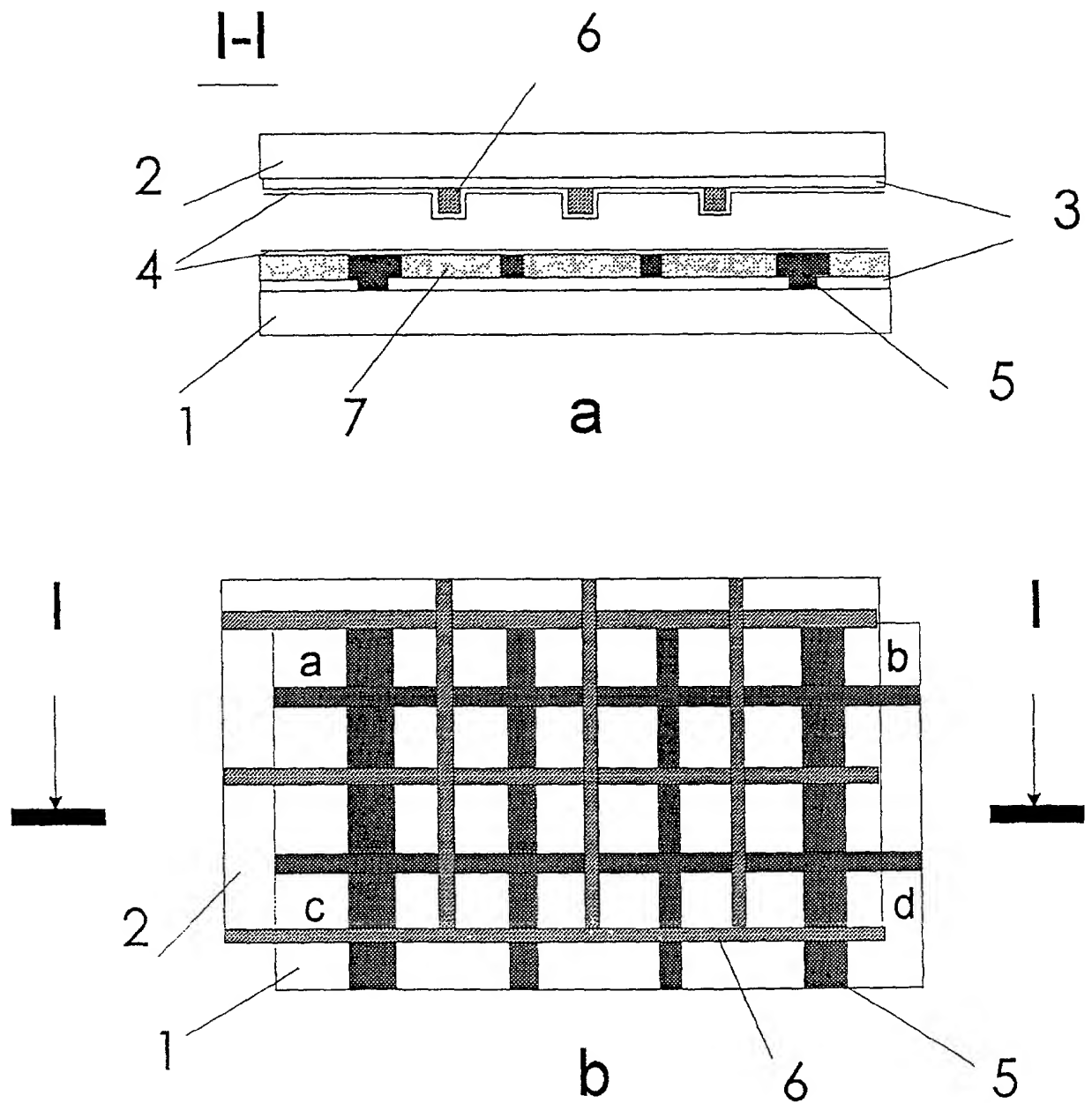


Fig. 5

09/529948

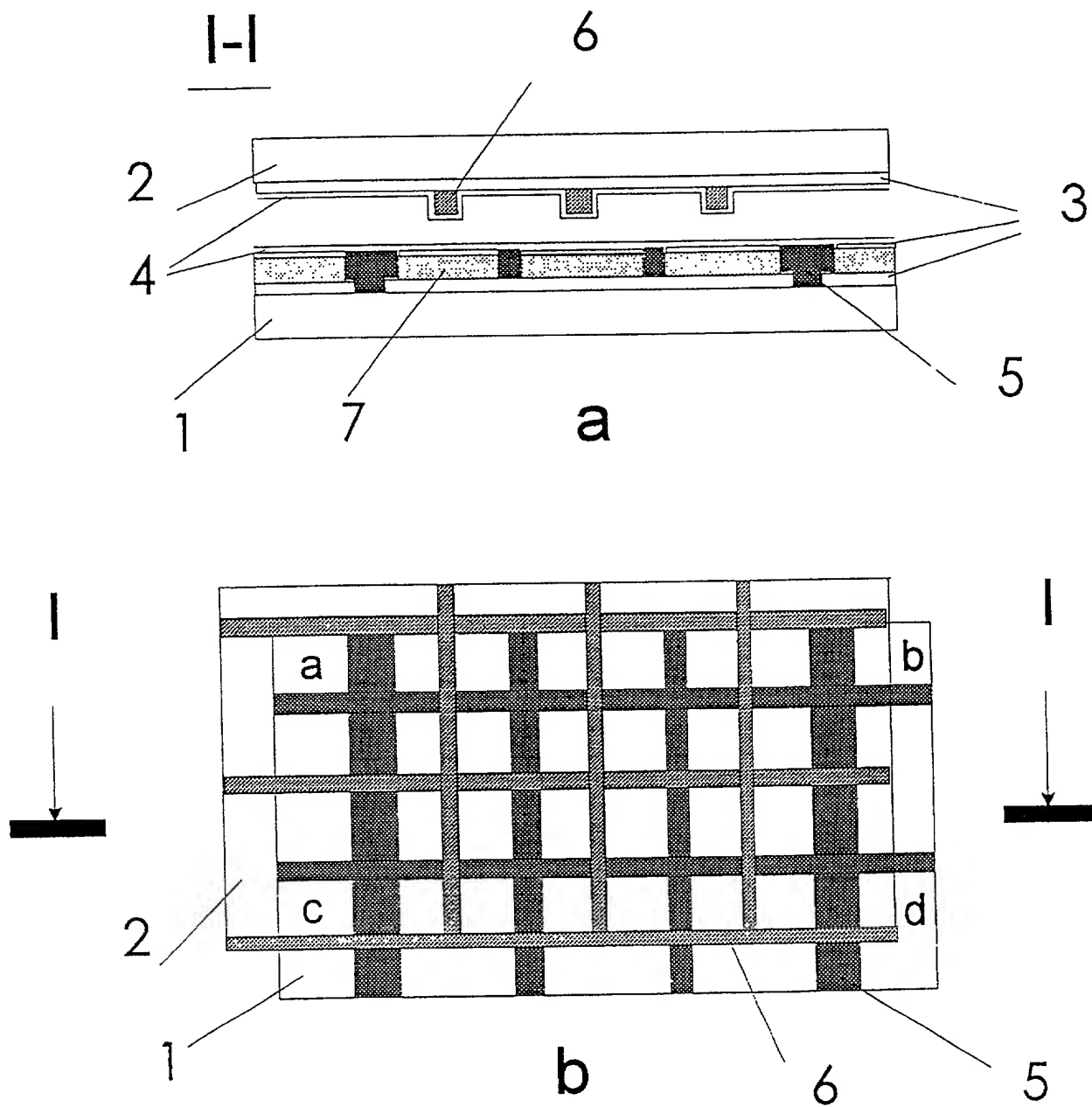


Fig. 6

09/529948

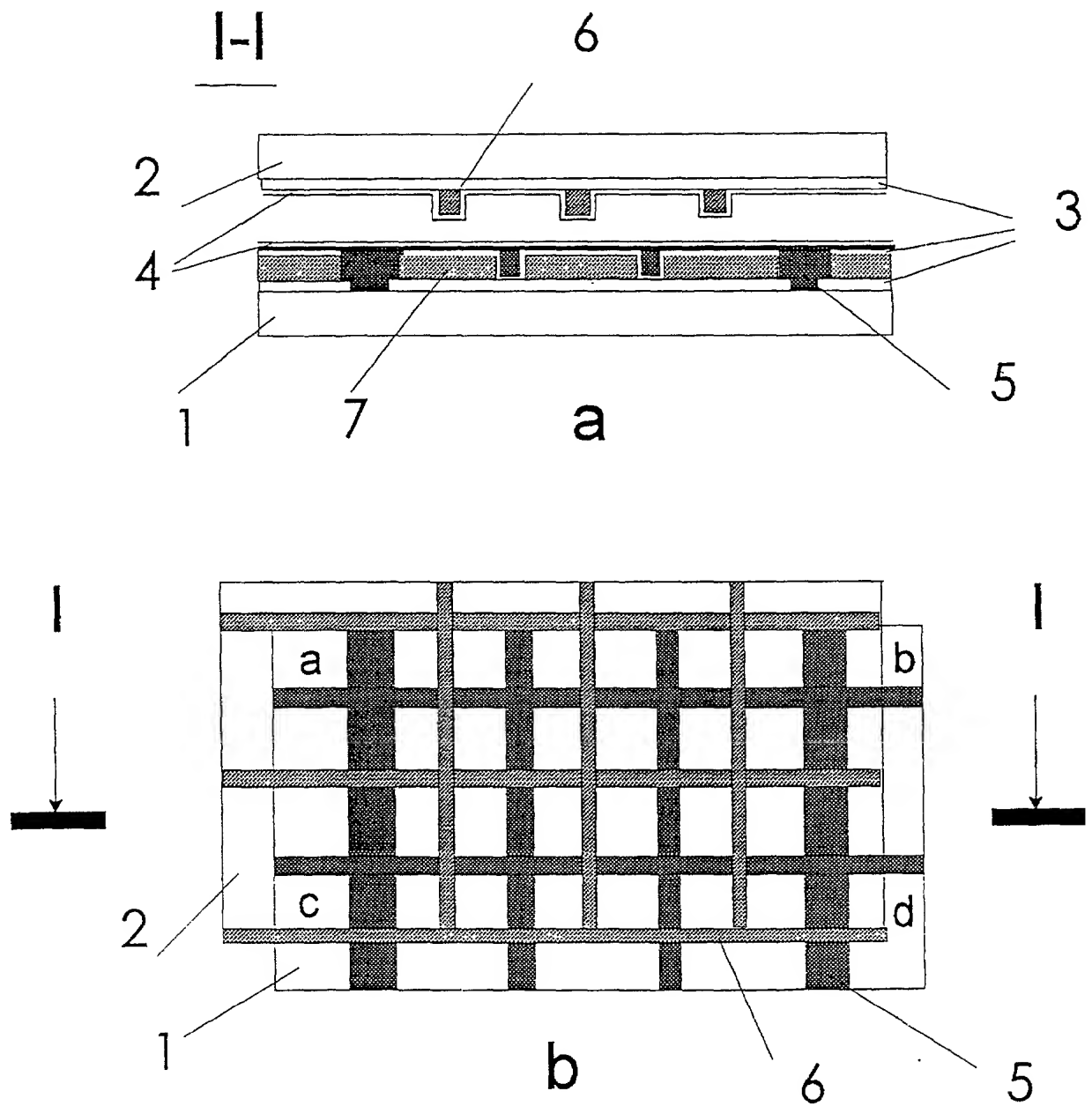


Fig. 7

09/529948

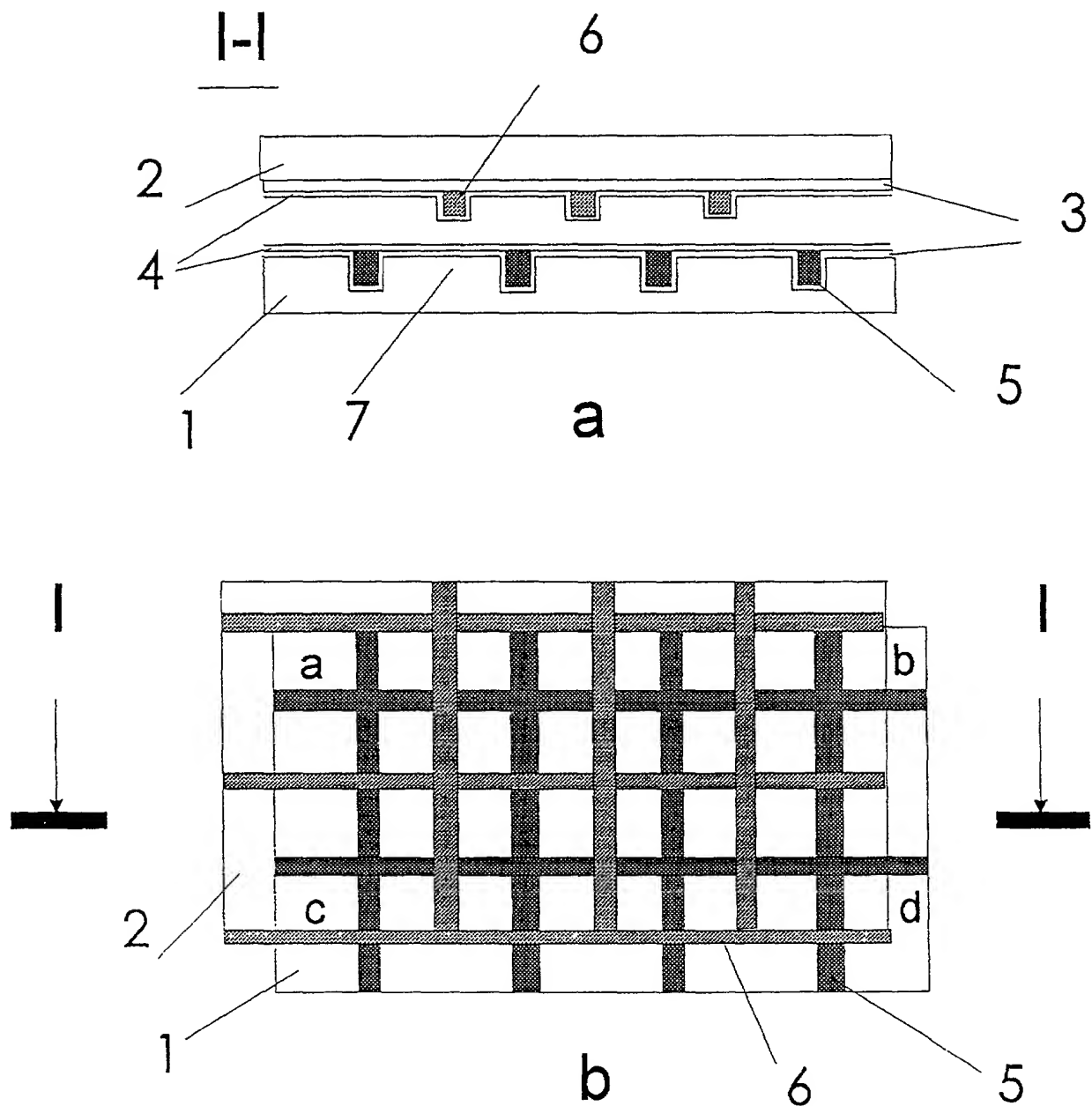


Fig. 8

09/529948

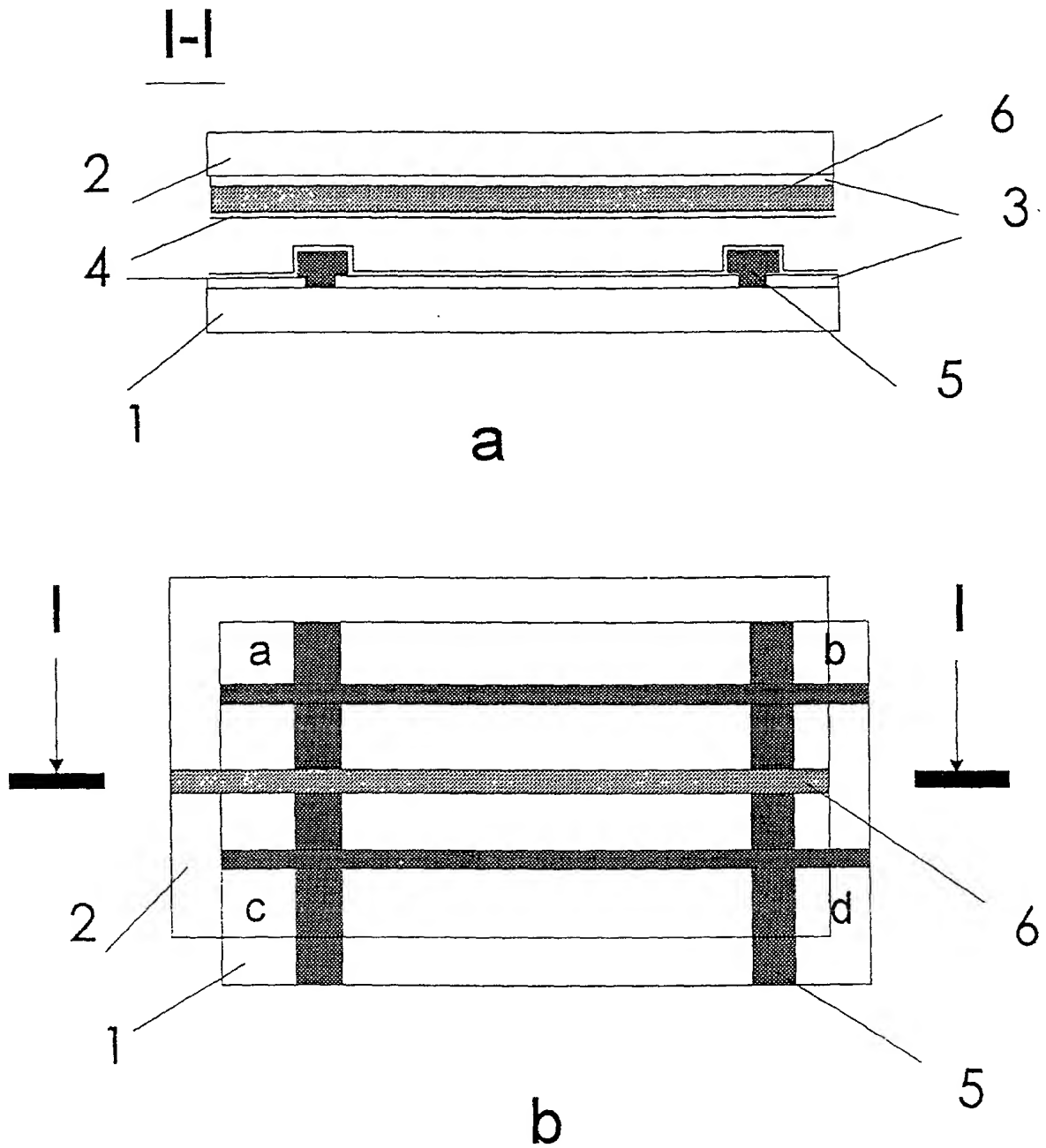


Fig. 9

**DECLARATION
and POWER OF ATTORNEY**

As a below named inventor, I declare that the information given herein is true, that I believe that I am the original, first and sole inventor if only one name is listed at 1 below, or a joint inventor if plural inventors are named below at 1-4, of the invention entitled.

which is described and claimed in ☐ the attached specification, or ☒ the specification in PCT Application No. PCT/BY98/00008 ✓ filed September 25, 1998 ☐ as amended on _____ (if applicable),

and for which a patent is sought, and that my residence, post office address and citizenship are as stated below next to my name.

I acknowledge my duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING Month Day Year	PRIORITY CLAIMED UNDER 35 U.S.C. 119
BELARUS	19980744	August 6, 1998	YES

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application

(Application Number) (Filing Date) (Status)

POWER OF ATTORNEY As a named inventor, I hereby appoint the following attorney(s) and/or Agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

STEVEN B. KELBER, Reg. No. 30,073, MARC R. LABGOLD, Ph.D., Reg. No. 34,651, SONG K JUNG, Reg. No. 35,210, SHARON E. CRANE, Ph.D., Reg. No. 36,143, CATHERINE BAX RICHARDSON, Reg. No. 39,007, KENNETH D. SPRINGER, Reg. No. 39,843, JAMES M. HEINTZ, Reg. No. 41,828, and AMY L. MILLER, Reg. No. 43,804.

Send correspondence to
Long Aldridge & Norman, LLP
701 Pennsylvania Avenue, N.W.
Suite 600
Washington, D.C. 20004

Direct telephone calls to
Song K Jung
(202) 624-1250

(Please print)

1	Name of Inventor	LAST NAME <u>Yakovenko</u>	FIRST NAME <u>Sergey</u>	MIDDLE NAME <u>E</u>	Residence CITY <u>Minsk</u> <u>Byx</u>	STATE OR COUNTRY BELARUS
	Post Office Address					COUNTRY OF CITIZENSHIP BELARUS
2	Name of Inventor	LAST NAME <u>Konovalev</u>	FIRST NAME <u>Victor</u>	MIDDLE NAME <u>A</u>	Residence CITY <u>Minsk</u> <u>Byx</u>	STATE OR COUNTRY BELARUS
	Post Office Address	<u>Yakubova Street, 66-4-26, Minsk, 220095, Belarus</u>				COUNTRY OF CITIZENSHIP BELARUS
3	Name of Inventor	LAST NAME <u>Muravsky</u>	FIRST NAME <u>Anatoly</u>	MIDDLE NAME <u>A</u>	Residence CITY <u>Minsk</u> <u>Byx</u>	STATE OR COUNTRY BELARUS
	Post Office Address	<u>Plekhanova Street, 53-88, Minsk, 220085, Belarus</u>				COUNTRY OF CITIZENSHIP BELARUS
4	Name of Inventor	LAST NAME <u>Timofeev</u>	FIRST NAME <u>Sergey</u>	MIDDLE NAME <u>N</u>	Residence CITY <u>Minsk</u> <u>Byx</u>	STATE OR COUNTRY BELARUS
	Post Office Address	<u>Kakhovskaya Street, 34-9, 220068, Minsk, Belarus</u>				COUNTRY OF CITIZENSHIP BELARUS

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon

Signature of INVENTOR 1	Signature of INVENTOR 2
DATE: <u>8.11.1999</u>	DATE: <u>8.11.1999</u>
Signature of INVENTOR 3	Signature of INVENTOR 4
DATE: <u>8.11.1999</u>	DATE: <u>08.11.1999</u>